A Waveguide Slot Array Antenna with Integrated T-shaped Filters in the Corporate-feed Circuit

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***Abstract*—In this paper, we demonstrate a waveguide slot array antenna by integration of T-shaped filters using the diffusion bonding of laminated thin metal plates. The excellent performance of the T-shaped filter has been experimentally verified by the in-band transmission and the out-of-band rejection of the fabricated antenna.**

***Keywords*—filter, waveguide slot array antenna, corporate-feed.**

I. Introduction

A filter and an antenna could be critical components in communication systems. Generally speaking, the filters are placed right after the antenna individually. There is a trend to integrate the filter and the antenna into a single module, so called filtering antenna, with simultaneous filtering and radiating functions with lower cost and compact size. Many research have been done to address this topic based on a microstrip line [1] or a dielectric-filled waveguide [2]. However, they suffer from the significant conductor, radiation and dielectric losses. Such losses would result in the degradation of antenna performance in terms of gain and efficiency, especially in the millimeter-wave band.

In this paper, a corporate-feed hollow-waveguide slot antenna with band-pass filtering response fabricated by the diffusion bonding of laminated thin metal plates is proposed, as shown in Fig. 1. Its radiating elements are the same with the ones in [3] that covers 71-86 GHz, while E-band T-shaped bandpass filter with wide bandwidth have been designed and then integrated into the limited space of the corporate feeding circuit. The slot array antenna including the T-shaped filter have been fabricated and measured to validate the feasibility of the design approach.

II. Design and Integration of Filter

The geometric configurations of the T-shaped filter is given in Fig. 2. The T-shaped filter is composed by 10 coupled cavity resonators marked from Cavities 1 to 10. Among the cavities, Cavities 1 and 2 are co-shared cavities thus the order of the filtering response of each channel, namely, S_{21} and S_{31}, is six. Cavity 2 is arranged at the T-junction, therefore the power from Port 1 is equally divided to Ports 2 and 3 if the coupling strength

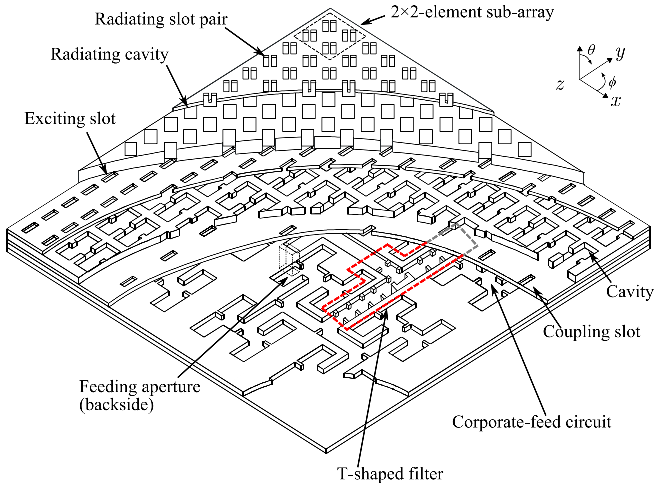


Fig. 1. Geometric configuration of the 16×16-element array antenna with integrated T-shaped filters.

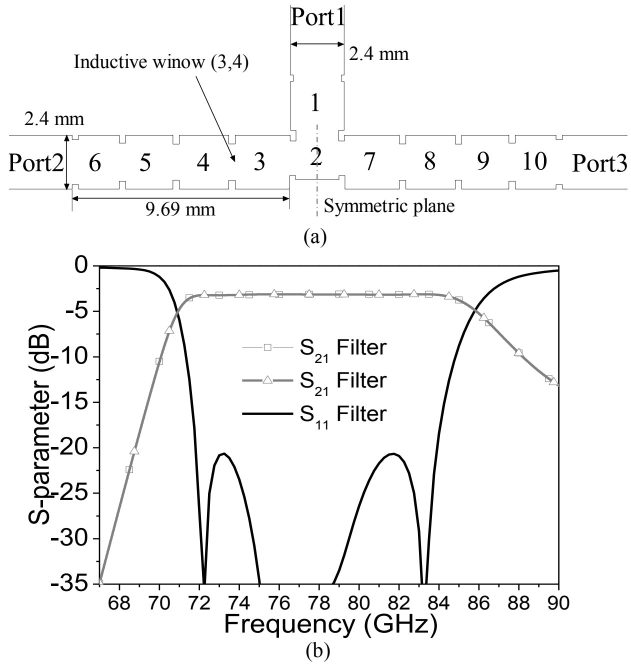


Fig. 2. Proposed T-shaped bandpass filter. (a) Structure. (b) Simulated results.

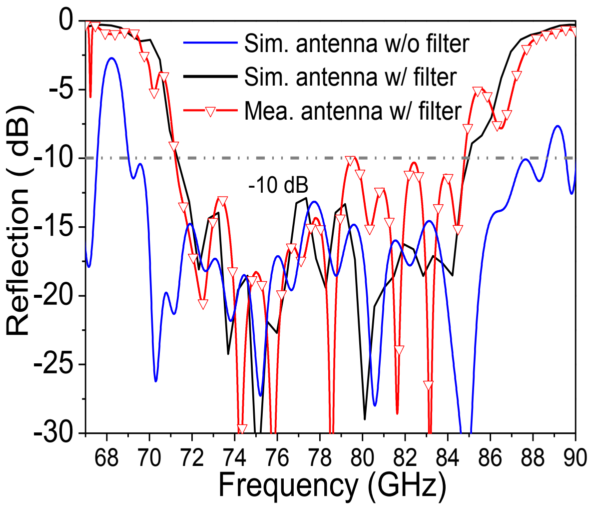
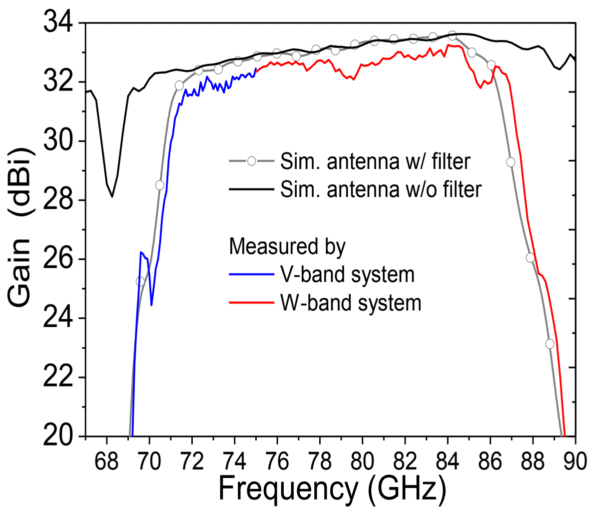
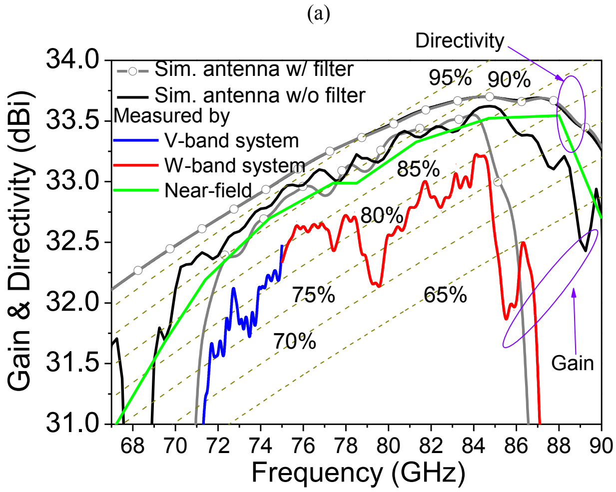


Fig. 3. Frequency characteristics of reflection.



(a)



(b)

Fig. 4. Frequency characteristics of gain and directivity.

to Cavity 3 and that to Cavity 7 are equal. Due to the field distribution characteristics of the TE_{101}-mode utilized in Cavity 2, the ideal phase difference between Ports 2 and 3 is zero. The synthesis procedure of the coupling matrix of the proposed 3-port T-shaped filter is similar to that of a 2-port filter with the 6-th order coupled resonators [4]. The specific bandwidth of the filter is set to be narrower in comparison with the original antenna so that the filtering function could be more visibly exhibited in the antenna response.

The simulated result shows the filter has the center frequency of 78.5 GHz with 3-dB bandwidth of 20.1%. The in-band reflection < –20.0 dB is 15.4% (71.83-83.91) GHz, corresponding to the in-band insertion loss from 0.11 to 0.31 dB. The transmission-rejection level at 67 and 90 GHz are 31.9 and 9.2 dB.

III. Results of the 16×16-Element Array with the T-Shaped Bandpass Filtere

The filtering antenna with the T-shaped filter is fabricated and then measured. The measured reflection, gain and directivity are provided in Fig. 3 and Fig. 4.

The measured results support the bandwidth for reflection lower than –10.0 dB of 17.2 %, 13.4 GHz (71.3–84.7 GHz), which shows good agreement with its simulated counterpart. Outside the passband, the reflection gradually increases expect some spurious frequencies which possibly come from the feeding circuit.

At the center frequency of 78.5 GHz, there is 33.0-dBi directivity, 32.7-dBi gain, and 82.7% antenna efficiency, the loss from the filter is estimated to be 0.2 dB. Within the passband of 71.3–84.7 GHz, the antenna efficiency more than 70% is fully supported. The gain is more than 32 dBi over 73.6–84.7 GHz. Outside the passband, the shape of the gain agrees well with the simulated result, reaching −1.27 and 17.1 dBi at 67 and 90 GHz, respectively.

IV. Conclusion

We propose the corporate-feed hollow-waveguide array antenna with fully integrated T-shaped filters. The measured results show that greater than 70% antenna efficiency with higher than 31.5 dBi is achieved over the 71.3–84.7 GHz, while significant gain-reduction is observed outside the passband.

References

[1] C. T. Chuang and S.-J. Chung, “Synthesis and design of a new printed filtering antenna,” *IEEE Trans. Antennas Propag.*, vol. 59, no. 3, pp. 1036–1042, Jan. 2011

[2] H. Chu, J. Chen, J. X. Chen, and Y. X. Guo, “A 3-D millimeter-wave filtering antenna with high selectivity and low cross-polarization,” *IEEE Trans. Antennas Propag.*, vol. 63, no. 5, pp. 2375–2380, Mar. 2015.

[3] T. Tomura., J. Hirokawa, T. Hirano, and M. Ando, “A 45° linearly polarized hollow-waveguide 16×16-slot array antenna covering 71‑86 GHz band,” *IEEE Trans. Antennas Propag.*,vol. 62, no. 10, pp. 5061–5067, Oct. 2014.

[4] J.-S. Hong and M. J. Lancaster, *Microstrip Filters for RF/Microwave Applications*. New York: Wiley, 2001.